Announcing an opportunity to participate in a new
Departmental Research Initiative (DRI)
supported by the Office of Naval Research (ONR), entitled

Layered Organization in the Coastal Ocean (LOCO)

An approximately five year, up to $9M (total), multi-disciplinary research program
to begin during Fiscal Year 2004

Planning letters briefly describing research to be proposed under this DRI should be submitted to the Science Program Officer leading this program (322_BC@onr.navy.mil, 703-696-4590) **by 1 August 2003**.

DRI Goal: ***To understand the properties of densely concentrated, thin layers of planktonic biota that can occur in coastal ocean environments, and the interacting physical, chemical, biological and optical processes responsible for establishment, maintenance and breakdown of layers.***

Detailed in this announcement (below) is: (1) a brief description of the phenomenon that is the focus of the DRI (with reference to useful literature), (2) the scope and objectives of the DRI, (3) a general approach proposed to achieve these objectives, (4) the process and timetable of application for research support under the DRI.

BIOLOGICAL LAYERING IN THE COASTAL OCEAN – THE PHENOMENON

Modern developments in oceanographic instrumentation and *in situ* sampling techniques (e.g., slow profiling moorings, slow-drop instrument packages, profiling floats) have greatly aided in the detection of fine-scale features in marine environments. The episodic presence of thin, concentrated layers of phytoplankton and zooplankton within the water column has been one discovery resulting from such advancements. Though these so-called 'thin layers' range from only a few 10's of centimeters to a few meters in vertical extent (Cowles *et al.* 1998, Hanson and Donaghay 1998), they apparently can be continuous horizontally for at least kilometers (Donaghay and Osborn 1997, Rines *et al.* 2002) and persistent for days to weeks. Such spatial and temporal persistence distinguishes thin layers from microscale patches, and makes them unique and important phenomena in coastal and marine waters. Biota present within these layers are often highly concentrated, sometimes several orders of magnitude greater than only decimeters away, above or below the layer. Layers therefore not only have potentially great

biological and ecological importance, but also can strongly affect the optical and acoustical properties of the water column.

The most ambitious, focused, multidisciplinary field study of the thin layer phenomenon to date was conducted in 1996 and 1998 in East Sound, Washington, a fjord in the U.S. Pacific Northwest. Results from this study clearly indicate that thin layers are noteworthy for and can be described by their unique biological, physical, chemical, optical and acoustical properties (e.g., Figs. 1, 2).

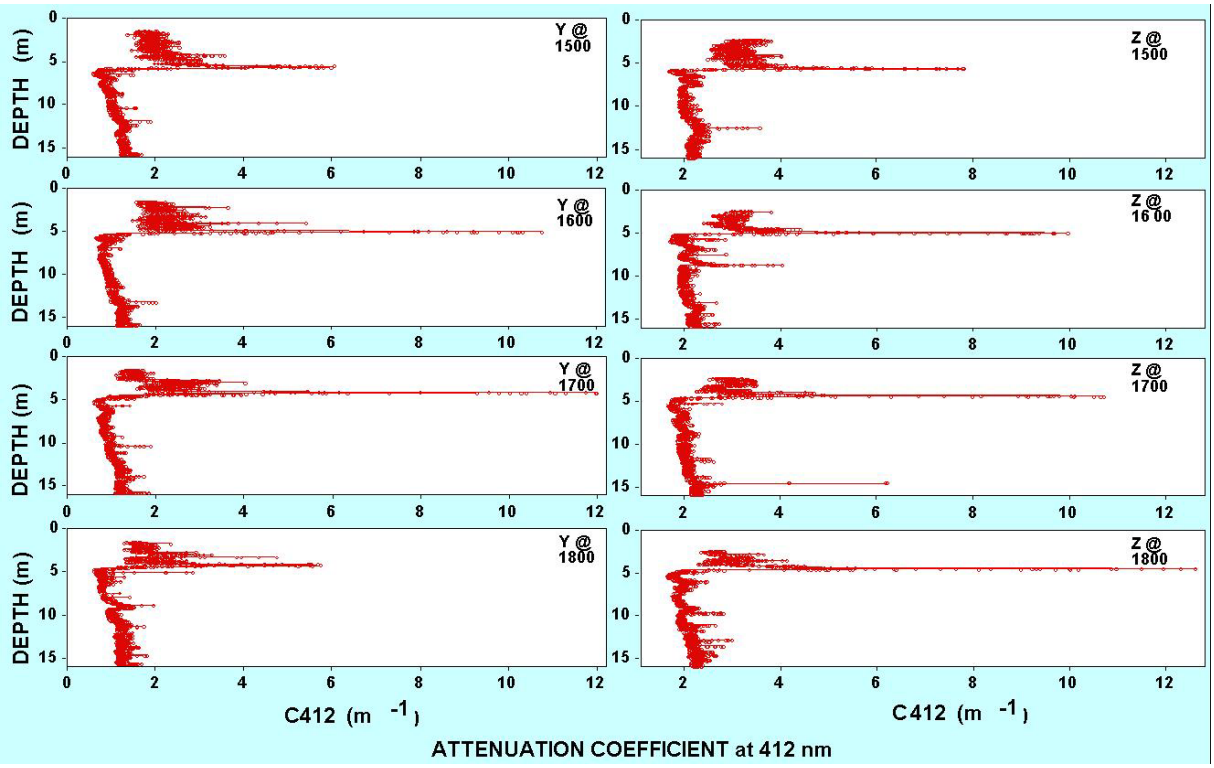

Figure 1. Vertical profiles of optical attenuation coefficient (412 nm) at two locations (X and Y, separated by several hundred meters) over a 4 hour period in East Sound, Washington in summer, 1998. A thin layer of ≈ 1 m thickness occurred at ≈ 5 m depth at both locations. Data and figure from Percy Donaghay (Univ. Rhode Island), used with permission.

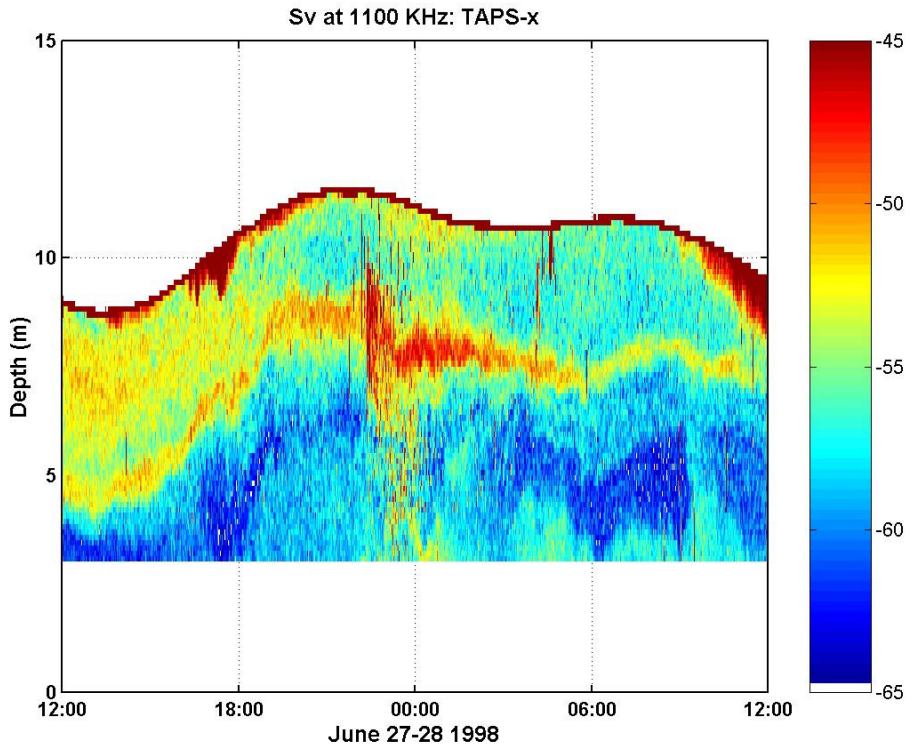

Figure 2. 24 hour time series of depth-dependent acoustic backscatter intensity (1100 kHz) obtained from a fixed, multi-frequency TAPS profiler deployed in East Sound, Washington on 27-28 June 1998. "Depth" (ending at sea surface) indicates height above fixed instrument. Fluctuations in "depth" track the mixed semi-diurnal tide. An intense internal scattering layer indicates zooplankton responding to a thin phytoplankton layer. Diel variability in intensity of this layer indicates a strong positive behavioral response by zooplankton to the layer, beginning at nightfall with zooplankton dispersing just before sunrise. Intense acoustic scattering near the sea surface is caused in part by bubbles, probably produced by degassing of oxygen supersaturated water produced in the phytoplankton layer. Data and figure from Van Holliday (BAE Systems, Inc.), used with permission.

Layers are typically comprised of dense phytoplankters which can vary in composition from diverse to near monospecific stands (e.g. Rines *et al.* 2002, see also http://www.gso.uri.edu/criticalscales/index.html). Layers are often associated with pycnoclines, or observed at the interface of water masses with unique flow signatures (Dekshenieks *et al.* 2001) (Fig. 3). Circulation dynamics and other physical processes may influence layer formation, though the mechanisms, and their importance relative to key biological processes such as productivity, behavior and grazing, are not well understood.

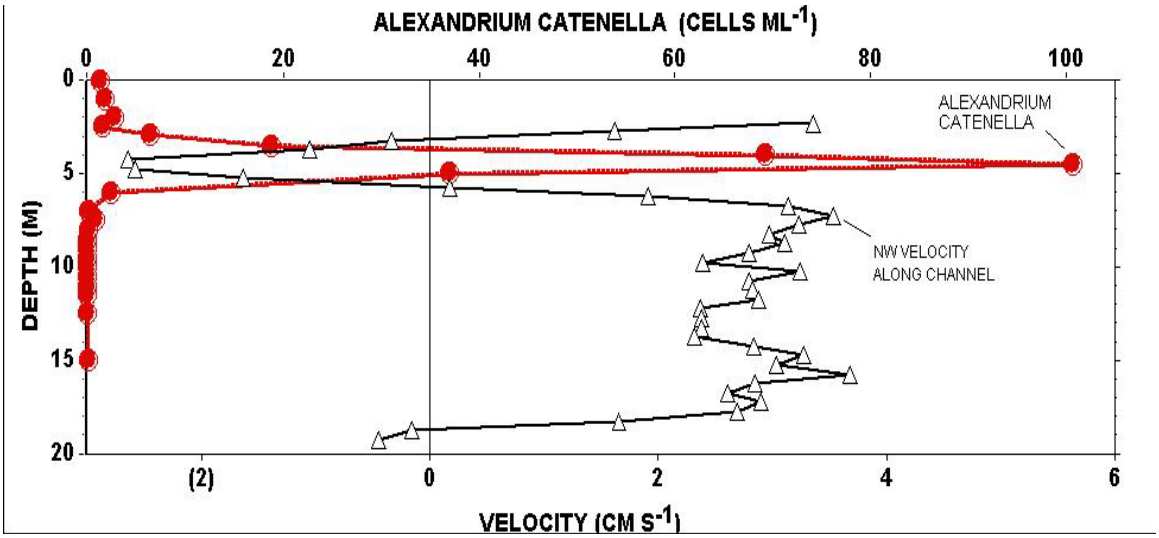

Figure 3. Vertical profiles of *Alexandrium* cell concentration (red line) and horizontal velocity along the main axis of the fjord (black line, positive into the fjord) at one station in East Sound, Washington during summer, 1998. *Alexandrium* were associated primarily with a thin layer of water at 5 m depth at that time moving toward the mouth of the fjord. Data and figure from Percy Donaghay, Jan Rines, Jim Sullivan (all at Univ. Rhode Island) and Margaret McManus (Univ. California Santa Cruz), used with permission.

The dense concentrations of plankton in thin layers may have considerable implications for rates of primary production and zooplankton grazing in the water column (e.g., Bjornsen and Nielsen 1991, Tiselius 1992, Cowles *et al.* 1998). For example, the temporally and spatially persistent accumulations of phytoplankton in these layers could be a significant food resource for migrating zooplankton, which seem to aggregate in or near layers, sometimes in a diel pattern (Fig. 2, see also Hanson and Donaghay 1998).

The optical scattering and absorption produced by aggregations of biota into thin layers can reduce light penetration through the layer by > 99%, resulting in a substantial optical signature associated with the layer (Fig. 1, see also Petrenko *et al.* 1998). In addition, both high densities of zooplankton as well as micro-bubble production from oxygen-supersaturated water within the layer can affect sound scattering in the water column. Layers thereby produce intense acoustical signatures as well (Fig. 2, see also Holliday *et al.* 1998).

Results reviewed above come from studies in one fjord in the Pacific Northwest. However, evidence of thin layers has been noted in a number of coastal ocean locales as well, including Monterey Bay, California; the northern Gulf of Mexico; the West Florida shelf; nearshore regions of the South Atlantic Bight and Southern California coast; and the Oregon shelf.

SCOPE AND GOALS OF THE DRI

The DRI, entitled *Layered Organization in the Coastal Ocean (LOCO)*, is being developed and will be administered by a partnership among three programs in ONR: Biological & Chemical Oceanography (322BC); Physical Oceanography (322PO); and Environmental Optics (322OP).

It is obvious from results obtained to date (see above and references provided) that intense and thin layers of biota occur not uncommonly in coastal ocean locales. These layers can have extremely strong optical and acoustical signatures manifested over a broad frequency range in both types of signal. Layers are of potentially immense biological importance (e.g., they can contain up to 75% of total depth-integrated biomass in a layer < 1 m thick), and they appear to be driven by both physical and behavioral processes. Layers are spatially expansive and long lasting, but ephemeral in both time and space.

Despite how much is understood about this phenomenon we are humbled by the breadth of what we do not know. For example, we have a comparatively poor understanding of:

- The physical oceanographic conditions under which layers form and break down in the coastal ocean;
- The spatial coherence and pattern, and temporal persistence, of layers in the coastal ocean (and what determines these properties);
- Interactions between and the relative importance of physical (e.g., shear, stability, mixing intensity, internal wave dynamics) and biological (e.g., productivity, grazing, aggregative swimming behaviors) processes that should impact layers;
- Chemical properties of layers and waters immediately adjoining layers (they will certainly impact the biota); and,
- Impacts of layers on inherent optical properties (IOP's) and bioluminescent properties of the water column, and the detectability of layers via remote optical methods.

The purpose of the DRI is to undertake basic research that will help to fill some of these huge gaps in our understanding of this phenomenon. More specifically, the ***objectives*** of the DRI are:

1. To understand the physical, biological, chemical and optical *properties* of vertically thin, horizontal layers of biota and biogenic particles in coastal oceans, and *processes responsible* for the formation, maintenance and dissipation of layers;
2. To understand the *spatial expanse and spatial properties* of layers in the coastal ocean (especially in terms of optical properties), as well as the *temporal durability* of layers, where they occur;
3. To begin to understand how common and widespread thin biological layers are in the coastal ocean; and,
4. To use information gleaned in achieving objectives (1) - (3) to begin to develop an ability to *predict* layer formation and presence in the coastal ocean.

To achieve these objectives a wide range of research programs need to be supported and integrated. These research programs individually and collectively should be designed to answer important questions posed to directly address the above objectives. ***Important research questions*** might include (but may not be restricted to) the following:

1. Under what *physical conditions* are layers created and broken down in the coastal ocean? How do these conditions contribute to layer formation or breakdown?

2. What are the *biological* (including bioluminescent) *properties* of layers, and what are the inherent biological *rates* (e.g., primary production rate, grazing rate) inside and outside of layers?
3. How *spatially expansive* are layers, and what are their *spatial properties*? (For example, are they continuous or perforated? To what extent do they thin or thicken over scales of kilometers?)
4. What are the *temporal* (i.e. diel to weekly) *scales* associated with layers?
5. How are spatial and temporal scales of layers governed by the interacting physical, chemical, optical and biological properties of the coastal ocean?
6. What are the *chemical properties* of layers and adjoining waters in the coastal ocean, and how do these properties contribute to the biological properties and rates?
7. To what extent does the *published literature* and *archived data* indicate the presence of biological layers in coastal ocean locales? Can the literature or historical data contribute insights into conditions responsible for layer formation, maintenance and breakdown?

POSSIBLE RESEARCH APPROACH

The research to be undertaken to address these (and related) objectives and specific questions will be driven in large measure by ideas promoted by researchers within the scientific community. Nevertheless, a general means of addressing the topic, that can help guide the development of specific research ideas, is outlined here. Researchers considering an application to ONR for support under this DRI should consider the following as a candidate approach, and not a firm commitment by ONR to a pre-defined plan that will *de facto* exclude alternative methods.

One promising approach to addressing the range of questions posed above would be to carry out two parallel field efforts – a process study and a phenomenological study.

- *Process study* – this component of the program would address Objectives 1 and 2, above. It would focus on understanding the complex physical, biological, chemical, optical and bio-acoustical dynamics of the layer phenomenon at one coastal ocean site. This study would be the more integrated and interdisciplinary of the two studies. It would consider rates, as well as pattern and processes. It would attempt to lead to an understanding of how potentially governing processes interact to determine set up, maintenance, and breakdown of layers. To carry out this study one-month, fully integrated field programs might take place at one site known to exhibit layering in years 2 and 3 of the DRI (FY's 2005 and 2006)

- *Phenomenological study* - this component of the program would address Objectives 2 and 3, above. It would focus on spatial mapping of layers at several sites (possibly including the site of the Process Study in one year), in order to begin to understand how common and widespread thin biological layers are in the coastal ocean, and what are the spatial-optical properties of layers where they occur. Technique(s) capable of broad, continuous spatial mapping of internal water-column bio-optical properties might be combined with established, high-resolution vertical measurements (e.g., from a profiling mooring or slow-drop bio-optical instrument package) that could provide critical ground truth data

for comparison with results from the mapping technique(s). Mapping of the phenomena might occur at least at three sites over a four-year period.

Given the candidate approach just outlined, a possible timetable for the DRI program might look as follows:

	FY 04	**FY 05**	**FY 06**	**FY 07**	**FY 08**
Process Study	Proposal selection, workshop; acquire and develop gear & test	One-month field study – Site A	One-month field study – Site A (or B); Data analysis	Data analysis & publication	Data analysis & publication
Phenom-enological Study	Proposal selection, workshop; acquire gear & test cruise	Field mapping – Site A	Field mapping – Site B; Data analysis	Field mapping – Site C; Data analysis	Data analysis & publication

APPLICATION FOR RESEARCH SUPPORT & TIMETABLE

Researchers wishing to apply for research support under the DRI are expected to submit a short (approximately 2 - 3 page) planning letter to the Science Program Officer leading this program (322_BC@onr.navy.mil, 703-696-4590) **by 1 August 2003**. Prior to writing and submitting the planning letter it may be wise to discuss ideas with ONR personnel in any of the programs in the DRI partnership (Biological & Chemical Oceanography (322BC); Physical Oceanography (322PO); and Environmental Optics (322OP) – contact information provided below), or with other potential research collaborators in the DRI program.

The planning letter should:

1) clearly and concisely describe the nature and objectives of the work you wish to propose,
2) indicate the amount of time needed to conduct the research,
3) provide an estimate of funds required by year (if applicable, days of ship time and class of ship required should be clearly noted but not included in your budget estimates), and
4) also include a 1-2 page CV for each principal investigator, including phone numbers and e-mail address.

The DRI program will span approximately five years with a total budget of up to $9M. Available funds will not be evenly divided among years, but instead will be weighted somewhat more heavily toward the middle years of the program during the time field programs are to be carried out. In developing research plans and operating budgets potential participants must

consider the program's budget limitations and recognize that many researchers must be supported to accomplish the program's objectives.

Planning letters can be sent via e-mail to 322_BC@onr.navy.mil (preferably as an attachment in the form of a Word document file, rich-text-format file, PDF file, or simple text file), or, especially if file size is large (> 1 MB), via our web-based file transfer mechanism (http://onroutside.onr.navy.mil/aspprocessor/biochem322/). Alternatively (though less desirable), planning letters (4 copies) may be sent by surface mail to ONR 322BC, Office of Naval Research, 800 North Quincy St., Arlington, VA 22217-5660, or faxed (Attn: Code 322BC) to 703-696-3390.

After careful review of the planning letters, an ONR Program Officer will respond to indicate whether or not submission of a full proposal is encouraged.

The projected timetable for requesting research support, and evaluation of requests by ONR, is summarized as follows:

1 AUGUST 2003:	planning letters due
1 OCTOBER 2003:	recommendations on planning letters announced
21 NOVEMBER 2003:	formal proposals due to ONR
Early JANUARY 2004:	organizational workshop
Early FEBRUARY 2004:	possible proposal revisions due
Mid FEBRUARY 2004:	final funding decisions made
1 MARCH 2004:	projects begin

Questions on the DRI or proposal process should be directed to any of the ONR Program Officers associated with the DRI:

Biological & Chemical Oceanography
322_BC@onr.navy.mil
703-696-4590

Physical Oceanography
322_PO@onr.navy.mil
703-696-4533

Environmental Optics
322_OP@onr.navy.mil
703-696-4532 or 703-696-4732

SOME PERTINENT REFERENCES

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